SPECIFICATION

Title of the Invention :

    RADIO RECEPTION APPARATUS

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RADIO RECEPTION APPARATUS

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a radio reception
apparatus used in a digital radio communication system.

Description of the Related Art

In digital communications, establishing time
synchronization between a transmitter and receiver is
a technology of extreme importance. Generally, using a
series of known signals, this technology performs
processing of calculating a correlation between a series
of known signals contained in a reception signal and a
series of known signals of the receiver and determines
synchronization based on the correlation value.
Establishing synchronization is difficult especially
when there is a frequency or time shift between the
transmitter and receiver such as immediately after power
is turned on and at the same time establishing
synchronization requires performance with high
sensitivity and high accuracy. The technology
disclosed in the Unexamined Japanese Patent Publication
No.HEI 6-252966 is known as one of time synchronization
methods capable of handling such a frequency shift.

However, the conventional time synchronization
method handling frequency shifts disclosed in the above
publication uses the same principle as that of delay
detection for calculating a vector difference during a
one-symbol time, and therefore the sensitivity

deteriorates down to approximately 3 dB. For this reason,
it is difficult to expect high performance from the
conventional system in the case of a long-distance
communication where the quality of the reception signal
5   is not much expected or a communication system using
radio waves of weak output.

<center>SUMMARY OF THE INVENTION</center>

It is an object of the present invention to provide
a radio reception apparatus using a vector difference
10   method capable of handling frequency shifts, drastically
improving the sensitivity and stably establishing
synchronization even in a communication environment with
feeble reception signals.

This object can be attained by performing vector
15   addition processing before calculating difference
vectors. Through this addition processing before
calculating difference vectors, the signal component and
error component are subjected to a vector addition and
power addition, respectively, providing an advantageous
20   feature that the signal-to-noise ratio (CNR) is
relatively improved.

<center>BRIEF DESCRIPTION OF THE DRAWINGS</center>

The above and other objects and features of the
invention will appear more fully hereinafter from a
25   consideration of the following description taken in
connection with the accompanying drawing wherein one
example is illustrated by way of example, in which;

FIG.1 is a block diagram showing a configuration

of a radio reception apparatus according to Embodiment 1 of the present invention;

FIG.2A illustrates an I signal of a reception signal;

5 FIG.2B illustrates a Q signal of the reception signal;

FIG.2C is a synchronization estimation signal according to a conventional synchronization method;

FIG.2D is a synchronization estimation signal 10 according to a synchronization method of the present invention;

FIG.3 is a block diagram showing a configuration of a radio reception apparatus according to Embodiment 2 of the present invention;

15 FIG.4 is a block diagram showing a configuration of a radio reception apparatus according to Embodiment 3 of the present invention;

FIG.5 is a block diagram showing a configuration of a radio reception apparatus according to Embodiment 20 4 of the present invention;

FIG.6 is a block diagram showing a configuration of a radio reception apparatus according to Embodiment 5 of the present invention;

FIG.7 is a block diagram showing a configuration 25 of a radio reception apparatus according to Embodiment 6 of the present invention;

FIG.8 is a block diagram showing a configuration of a radio reception apparatus according to Embodiment

7 of the present invention;

FIG.9 is a block diagram showing a configuration of a radio reception apparatus according to Embodiment 8 of the present invention;

5   FIG.10 is a block diagram showing a configuration of a radio reception apparatus according to Embodiment 9 of the present invention; and

FIG.11 is a block diagram showing a configuration of a radio reception apparatus according to Embodiment 10 10 of the present invention.

DETAILED DESCRIPTION OF THE

PREFERRED EMBODIMENTS

With reference now to the attached drawings, embodiments of the present invention will be explained 15 in detail below.

(Embodiment 1)

This embodiment describes a radio reception apparatus using a vector difference method capable of handling frequency shifts that performs vector addition 20 processing before calculating difference vectors.

FIG.1 is a block diagram showing a configuration of a radio reception apparatus according to Embodiment 1 of the present invention. Here, the case where a radio reception apparatus is mounted on a communication 25 terminal apparatus will be explained.

A radio signal sent from the other end of communication is received by reception section 101 through antenna 100. Reception section 101 performs

predetermined radio reception processing (down-conversion, A/D conversion, etc.) and then demodulation processing on the reception signal. This demodulated signal 110 is output to shift register 102. Shift

5 register 102 stores demodulated signal 110 and outputs as reception signal 111 to convolver 104.

Convolver 104 is configured by delayer 1041 for reception signals, delayer 1042 for known signals, multiplier 1043 for multiplying a reception signal by

10 a known signal and adder 1044 for adding up the multiplication result of multiplier 1043.

Convolver 104 performs matched filtering processing between the reception signal output from shift register 102 and the known signal output from known

15 signal storage section 103 and outputs the processed value (correlation value) as short-term correlation signal 113 to difference calculation section 105. In this case, the length of delayer 1042 for known signals, that is, calculation series length 119 is determined by

20 calculation length determination section 118.

Difference calculation section 105 is configured by delayer 1051 for delaying short-term correlation signal 113, complex conjugator 1052 for finding a complex conjugate of delayed short-term correlation signal 113

25 and multiplier 1053 for multiplying short-term correlation signal 113 by the complex conjugate of the short-term correlation signal.

Difference calculation section 105 calculates

difference vectors corresponding to 1 symbol of short-term correlation signal 113 and outputs as correlation difference signal 114 to addition section 106. Addition section 106 adds up correlation

5   difference signal 114 corresponding to 1 series of known signals 112 and outputs as addition difference signal 115 to memory 107 and memory 107 stores addition difference signal 115.

Detection section 108 calculates the size of the

10   vector series of correlation signals 116 output from memory 107, searches maximum correlation signal 116 and outputs the detected information as detected signal 117.

Then, the operation of the radio reception apparatus having the above configuration will be

15   explained.

Shift register 102 that stores the demodulated signal demodulated by reception section 101 outputs calculation series length 119 (denoted as "s") given by calculation length determination section 118

20   corresponding to s symbols from the start (time $t + 0$) of an estimation range as reception signal 111 to reception signal delayer 1041 of convolver 104 (here, suppose calculation series length $s = 4$).

Known signal storage section 103 outputs s symbols

25   (here, suppose calculation series length $s = 4$) from a pre-stored known signal as known signal 112 to known signal delayer 1042 of convolver 104.

Convolver 104 performs matched filtering

processing (correlation calculation processing) between
reception signal 111 and known signal 112. That is,
convolver 104 multiplies reception signal 111 by known
signal 112 using their respective multipliers 1043 and

5   adds up their respective multiplication results using
adder 1044. Convolver 104 outputs the output of adder
1044 as short-term correlation signal 113 to difference
calculation section 105. This short-term correlation
signal 113 is recognized as a short-term correlation

10   signal at time (t+0).

     Then, shift register 102 outputs 4 symbols from the
symbol at time (t+1) when 1 symbol is shifted as reception
signal 111 to reception signal delayer 1041 of convolver
104. Known signal storage section 103 outputs 4 symbols

15   from the 2nd symbol as known signal 112 to known signal
delayer 1042 of convolver 104.

     In the same way as that described above, convolver
104 performs matched filtering processing and outputs
short-term correlation signal 113 at time (t+1) to

20   difference calculation section 105. In this way,
short-term correlation signals 113 are calculated from
time (t+0) to time (t+N-4) (N is the signal length of
the known signal series).

     Calculated short-term correlation signal 113 is

25   sequentially output to difference calculation section
105 and difference calculation section 105 calculates
difference vectors corresponding to 1 symbol of
short-term correlation signal 113. That is, delayer

1051 delays short-term correlation signal 113 by 1 symbol, complex conjugate section 1052 acquires a complex conjugate of short-term correlation signal 113 and multiplier 1053 multiplies short-term correlation

5 signal 113 by the complex conjugate of short-term correlation signal 113 delayed by 1 symbol. This calculation result is output as correlation difference signal 114 to addition section 106.

Correlation difference signal 114 obtained in this

10 way is calculated for 1 series of known signals 112. Addition section 106 adds up correlation difference signal 114 and outputs the addition result as addition difference signal 115 at time (t+0) to memory 107.

Likewise, addition difference signal 115 at time

15 (t+1) by replacing t with t+1 is calculated. Thus, addition difference signals 115 from time (t+0) to time (t+M-1) are stored in memory 107. At this time, storing the storage location and time information corresponding to addition difference signal 115 in memory 107 according

20 to, for example, a rule that the storage location = time information makes it easier to extract the time information from detection section 108, which will be described later.

Detection section 108 sequentially calculates the

25 size of the vector series of correlation signals 116 output from memory 107, searches correlation signal 116 of the maximum size, finds the size, storage location and its vector information and outputs this detected

information as detected signal 117. The
synchronization timing is thereby detected. The
detection may be performed by providing a predetermined
threshold to compare with a vector sequence, and
5   selecting a plurality of candidates exceeding the
threshold. Further, the detection may be performed by
setting the number of selected vector sequences to a
predetermined number, and selecting a predetermined
number of vector sequences in descending order of their
10   value.

At this time, the size of correlation signal 116
generally expresses a correlation value between
reception signal 101 and known signal 112 to be searched.
The greater this value, the more certain this information
15   can be. Next, the storage location shows a strong
correlation with the time information as described above,
and therefore it is easy to convert the storage location
to the time information. The time information at this
time indicates that known signal 112 to be searched is
20   within the detected time of reception signal 101.
Because of this, in a system in which a sync signal is
inserted in a specific location of burst, it is possible
to detect a sync signal in demodulated signal 110 by
regarding this sync signal as known signal 112 and the
25   reception burst signal as demodulated signal 110 and
thereby establish synchronization with the system.

Furthermore, by detection section 108 detecting m
peak positions and vectors from the maximum value of

correlation signal 116, it is also possible to estimate a multipath condition that occurs due to differences in the propagation path.

Here, the effects of performing matched filtering processing before calculating difference vectors will be explained. In a conventional difference vector calculation (delay detection), a difference vector is calculated between a reception signal and this reception signal delayed by one unit time (for example, 1-symbol time). Normally, a desired signal and noise are superimposed on a reception signal. Calculating a difference vector using the signal with the desired signal and noise superimposed would mean multiplying between signals with superimposed noise. On the other hand, coherent detection multiplies a reception signal with superimposed noise by a known signal without superimposed noise. For this reason, a signal detected by delay detection has a noise level greater by approximately 3 dB than a signal detected by coherent detection.

The present invention carries out matched filtering processing through convolver 104 before calculating difference vectors. In matched filtering processing, desired signal components are subjected to a vector addition, while noise components are subjected to a power addition. The result of this vector addition corresponds to the result of a power addition, and therefore power of a desired signal is affected by the

result of the vector addition at a rate of the square
thereof. Thus, calculating the power ratio of the
desired signal component to the noise component allows
a large gain to be obtained. This makes it possible to
5   detect a desired signal with a maximum C/N ratio (gain)
from a reception signal with superimposed noise.
Calculating difference vectors (delay detection) after
this means calculating difference vectors using a
reception signal without superimposed noise, and can
10   reduce the error rate of the signal after delay detection
as a result.

     The contents described above will be explained
using FIG.2A to FIG.2D. FIG.2A shows an I (in-phase
component) signal of a reception signal and FIG.2B shows
15   a Q (quadrature component) signal of the reception signal.
In order to eliminate a frequency offset as in the case
of the prior art, applying a difference vector
calculation to the I signal shown in FIG.2A and Q signal
shown in FIG.2B would mean a calculation between signals
20   with superimposed noise and deteriorate the C/N ratio
as shown in FIG.2C.

     The present invention applies matched filtering
processing using a known signal to the I signal shown
in FIG.2A and Q signal shown in FIG.2B first. This
25   increases the gain of the desired signal to noise and
improves the C/N ratio of the reception signal. Applying
a difference vector calculation to this signal with the
improved C/N ratio to eliminate the frequency offset will

improve the accuracy of detecting a synchronization estimation signal as shown in FIG.2D.

This embodiment describes the case where matched filtering processing is carried out by a convolver, but the present invention is also applicable to a case where matched filtering processing is carried out by a transversal filter or SAW filter.

This embodiment describes the case where calculation series length 119 (s) given by calculation length determination section 118 is 4, but the present invention is also applicable to a case where calculation series length s is not 4. The greater the calculation series length, the greater the effect of averaging noise is. For example, an improvement to the characteristic by averaging is expected by setting s=4, thus drastically alleviating the reception environment condition for establishing synchronization and offering prospects of great effects especially in a harsh CNR environment. On the other hand, since the phase is shifted for every symbol due to influences of frequency shifts, increasing calculation series length s will make the system more susceptible to frequency shifts, etc. For this reason, whether or not to increase calculation series length s up to a size equivalent to the known signal series length should be considered according to the situation as appropriate. The optimal value of this calculation series length s depends on conditions such as the symbol rate, frequency accuracy and system design. In general,

the frequency accuracy is sufficiently high with respect to the symbol rate, and therefore problems are not likely to occur if s is set within the range of 4 to 6.

Furthermore, this embodiment describes the method
5   of estimating the time during which known signal 112 exists from the peak position of correlation signal 116, but correlation signal 116 has various other characteristics and can also be used to estimate a multipath environment by detecting a plurality of peaks,
10 for example.

Furthermore, this embodiment describes the case of 1 sample per 1 symbol, but the present invention can also be implemented in the case of 4 samples per 1 symbol by setting a time step of addition difference signal 115
15 to 1/4 (t+0, t+1/4, t+2/4, t+3/4, t+1, t+5/4, …). Of course, there are no restrictions on the number of samples per 1 symbol and changing this step will make the present invention applicable to any number of samples.

20 (Embodiment 2)

This embodiment describes a case where a known signal is changed when matched filtering processing is performed by convolver 104.

FIG.3 is a block diagram showing a configuration
25 of a radio reception apparatus according to Embodiment 2 of the present invention. In FIG.3, the same components as those in FIG.1 are assigned the same reference numerals and detailed explanations thereof

will be omitted.

The radio reception apparatus shown in FIG.3 is provided with selection section 201 for selecting known signal 112 output from known signal storage section 103.

5 Therefore, the known signal output to known signal delayer 1042 of convolver 104 is selected known signal 202 selected from known signals stored in known signal storage section 103.

In the radio reception apparatus as configured
10 above, shift register 102 that stores demodulated signal 110 demodulated by reception section 101 outputs s symbols of calculation series length 119 (denoted as "s") given by calculation length determination section 118 from the start (time t+0) of the estimation range to
15 reception signal delayer 1041 of convolver 104 as reception signal 111 (here, suppose calculation series length s=4).

Selection section 201 selects one of n types of known signals stored in known signal storage section 103
20 and outputs s symbols (here, suppose calculation series length s=4) from the start of the selected known signal to known signal delayer 1042 of convolver 104 as selected known signal 202.

Convolver 104 performs matched filtering
25 processing between reception signal 111 and selected known signal 202. That is, convolver 104 multiplies reception signal 111 and selected known signal 202 using their respective multipliers 1043 and adds up their

respective multiplication results using adder 1044.
Convolver 104 outputs the output of adder 1044 as
short-term correlation signal 113 to difference
calculation section 105. This short-term correlation

5   signal 113 is recognized as a short-term correlation
signal at time (t+0).

Then, shift register 102 outputs 4 symbols from the
symbol at time (t+1) when 1 symbol is shifted as reception
signal 111 to reception signal delayer 1041 of convolver

10 104. Known signal storage section 103 outputs 4 symbols
from the 2nd symbol of the selected known signal as
selected known signal 202 to known signal delayer 1042
of convolver 104.

In the same way as that described above, convolver

15 104 performs matched filtering processing and outputs
short-term correlation signal 113 at time (t+1) to
difference calculation section 105. In this way,
short-term correlation signals 113 are calculated from
time (t+0) to time (t+N-4) (N is the signal length of

20 the known signal series).

Calculated short-term correlation signal 113 is
sequentially output to difference calculation section
105 and difference calculation section 105 calculates
difference vectors corresponding to 1 symbol of

25 short-term correlation signal 113. That is, delayer
1051 delays short-term correlation signal 113 by 1 symbol,
complex conjugate section 1052 acquires a complex
conjugate of the short-term correlation signal and

multiplier 1053 multiplies short-term correlation signal 113 by the complex conjugate of short-term correlation signal 113 delayed by 1 symbol. This calculation result is output as correlation difference signal 114 to addition section 106.

Correlation difference signal 114 obtained in this way is calculated for 1 series of selected known signals 202. Addition section 106 adds up correlation difference signal 114 and outputs the addition result as addition difference signal 115 at time (t+0) to memory 107.

Likewise, addition difference signal 115 at time (t+1) by replacing t with t+1 is calculated. Thus, addition difference signals 115 from time (t+0) to time (t+M-1) are stored in memory 107.

When the calculation of the first known signal series is completed, selection section 201 selects a second known signal series and carries out the above processing. The selection section 201 continues the above processing until the calculation of all (or some of) known signal series is completed.

At this time, storing the storage location, the type of a series of known signals and time information corresponding to addition difference signal 115 in memory 107 according to, for example, a rule that the storage location = (known signal series information, time information) makes it easier to extract the known signal series and time information from detection

section 108, which will be described later.

Detection section 108 sequentially calculates the size of the vector series of correlation signals 116 output from memory 107, searches correlation signal 116

5   of the maximum size, finds the size, storage location, the corresponding known signal series and its vector information and outputs this detected information as detected signal 117. Since the known signal series thus corresponds to the vector information, the detection of

10   a vector with the maximum size enables the known signal series corresponding to the vector to be specified.

At this time, the size of correlation signal 116 generally expresses a correlation value between reception signal 101 and known signal 112 to be searched.

15   The greater this value, the more certain this information can be. Next, the storage location shows a strong correlation with the time information as described above, and therefore it is easy to convert the storage location to the time information. The time information at this

20   time indicates that known signal 112 to be searched is within the detected time of reception signal 101. Because of this, in a system in which sync signals of a plurality of types are inserted in a specific location of burst, it is possible to detect the type and location

25   of a sync signal in demodulated signal 110 by regarding this sync signal as known signal 112 and the reception burst signal as demodulated signal 110 and thereby establish synchronization with the system.

Furthermore, by detection section 108 detecting m peak positions and vectors from the maximum value of correlation signal 116, it is also possible to estimate a multipath condition that occurs due to differences in the propagation path.

This embodiment describes the case where calculation series length 119 (s) given by calculation series length 118 is 4, but the present invention is also applicable to a case where calculation series length s is not 4. The greater the calculation series length, greater the effect of averaging of noise is. For example, an improvement to the characteristic by averaging is expected by setting s=4, thus drastically alleviating the reception environment condition for establishing synchronization and offering prospects of great effects especially in a harsh CNR environment. On the other hand, since the phase is shifted for every symbol due to influences of frequency shifts, increasing calculation series length s will make the system more susceptible to frequency shifts, etc.

For this reason, whether or not to increase calculation series length s up to a size equivalent to the known signal series length should be considered according to the situation as appropriate. The optimal value of this calculation series length s depends on conditions such as the symbol rate, frequency accuracy and system design. In general, the frequency accuracy is sufficiently high with respect to the symbol rate,

and therefore problems are not likely to occur if s is set within the range of 4 to 6.

Furthermore, this embodiment describes the method of estimating corresponding known signal 112 and the time during which known signal 112 exists from the peak position of correlation signal 116, but correlation signal 116 has various other characteristics and can also be used to estimate a multipath environment by detecting a plurality of peaks, for example.

Furthermore, this embodiment describes the case of 1 sample per 1 symbol, but the present invention can also be implemented in the case of 4 samples per 1 symbol by setting a time step of addition difference signal 115 to 1/4 (t+0, t+1/4, t+2/4, t+3/4, t+1, t+5/4, ···). Of course, changing this step otherwise will make the present invention applicable to any samples.

(Embodiment 3)

This embodiment describes a case where frequency estimation is performed using the detection information output from detection section 108.

FIG.4 is a block diagram showing a configuration of a radio reception apparatus according to Embodiment 3 of the present invention. In FIG.4, the same components as those in FIG.1 are assigned the same reference numerals and detailed explanations thereof will be omitted.

The radio reception apparatus shown in FIG.4 is provided with frequency estimation section 301 for

estimating a frequency based on the detection information output from detection section 108. Estimated frequency 302 estimated by frequency estimation section 301 is output.

5 In the radio reception apparatus as configured above, shift register 102 that stores demodulated signal 110 demodulated by reception section 101 outputs s symbols of calculation series length 119 (denoted as "s") given by calculation length determination section 118 10 from the start (time t+0) of the estimation range to reception signal delayer 1041 of convolver 104 as reception signal 111 (here, suppose calculation series length s=4).

Known signal storage section 103 outputs s symbols 15 (here, suppose calculation series length s=4) from the start of the known signal to known signal delayer 1042 of convolver 104 as known signal 112.

Convolver 104 performs matched filtering processing between reception signal 111 and known signal 20 112. That is, convolver 104 multiplies reception signal 111 by known signal 112 using their respective multipliers 1043 and adds up their respective multiplication results using adder 1044. Convolver 104 outputs the output of adder 1044 as short-term 25 correlation signal 113 to difference calculation section 105. This short-term correlation signal 113 is recognized as a short-term correlation signal at time (t+0).

Then, shift register 102 outputs 4 symbols from the symbol at time (t+1) when 1 symbol is shifted as reception signal 111 to reception signal delayer 1041 of convolver 104. Known signal storage section 103 outputs 4 symbols

5   from the 2nd symbol of the known signal as known signal 112 to known signal delayer 1042 of convolver 104.

In the same way as that described above, convolver 104 performs matched filtering processing and outputs short-term correlation signal 113 at time (t+1) to

10   difference calculation section 105. In this way, short-term correlation signals 113 are calculated from time (t+0) to time (t+N-4) (N is the signal length of the known signal series).

Calculated short-term correlation signal 113 is

15   sequentially output to difference calculation section 105 and difference calculation section 105 calculates difference vectors corresponding to 1 symbol of short-term correlation signal 113. That is, delayer 1051 delays short-term correlation signal 113 by 1 symbol,

20   complex conjugate section 1052 acquires a complex conjugate of the short-term correlation signal and multiplier 1053 multiplies short-term correlation signal 113 by the complex conjugate of short-term correlation signal 113 delayed by 1 symbol. This

25   calculation result is output as correlation difference signal 114 to addition section 106.

Correlation difference signal 114 obtained in this way is calculated for 1 series of known signals 112.

Addition section 106 adds up correlation difference
signal 114 and outputs the addition result as addition
difference signal 115 at time (t+0) to memory 107.

5   Likewise, addition difference signal 115 at time
(t+1) by replacing t with t+1 is calculated. Thus,
addition difference signals 115 from time (t+0) to time
(t+M-1) are stored in memory 107. At this time, storing
the storage location and time information corresponding
to addition difference signal 115 in memory 107 according
10   to, for example, a rule that the storage location = time
information makes it easier to extract the known signal
series and time information from detection section 108,
which will be described later.

      Detection section 108 sequentially calculates the
15   size of the vector series of correlation signals 116
output from memory 107, searches correlation signal 116
of the maximum size, finds the size, storage location
and its vector information and outputs this detected
information as detected signal 117.

20   At this time, the size of correlation signal 116
generally expresses a correlation value between
reception signal 101 and known signal 112 to be searched.
The greater this value, the more certain this information
can be. Next, the storage location shows a strong
25   correlation with the time information as described above,
and therefore it is easy to convert the storage location
to the time information. The time information at this
time indicates that known signal 112 to be searched is

within the detected time of reception signal 101.
Because of this, in a system in which sync signals of
a plurality of types are inserted in a specific location
of burst, it is possible to detect the type and location
of a sync signal in demodulated signal 110 by regarding
this sync signal as known signal 112 and the reception
burst signal as demodulated signal 110 and thereby
establish synchronization with the system.

Furthermore, by detection section 108 detecting m
peak positions and vectors from the maximum value of
correlation signal 116, it is also possible to estimate
a multipath condition that occurs due to differences in
the propagation path.

Furthermore, this correlation signal 116 performs
a convolution calculation between reception signal 111
and known signal 112, removes the information component
and uses the difference vector, and in this way the vector
angle includes a frequency component. Frequency
estimation section 301 detects the frequency component
from detected signal 117 output from detection section
108 and outputs estimated frequency 302. This estimated
frequency 302 can be generally used as a frequency shift
between the transmitter and receiver and estimated
frequency 302 can also be used as the control signal of
frequency control, for example.

This embodiment describes the case where
calculation series length 119 (s) given by calculation
series length 118 is 4, but the present invention is also

applicable to a case where calculation series length s is not 4. The greater the calculation series length, greater the effect of averaging of noise is. For example, an improvement to the characteristic by averaging is expected by setting s=4, thus drastically alleviating the reception environment condition for establishing synchronization and offering prospects of great effects especially in a harsh CNR environment. On the other hand, since the phase is shifted for every symbol due to influences of frequency shifts, increasing calculation series length s will make the system more susceptible to frequency shifts, etc.

For this reason, whether or not to increase calculation series length s up to a size equivalent to the known signal series length should be considered according to the situation as appropriate. The optimal value of this calculation series length s depends on conditions such as the symbol rate, frequency accuracy and system design. In general, the frequency accuracy is sufficiently high with respect to the symbol rate, and therefore problems are not likely to occur if s is set within the range of 4 to 6.

This embodiment describes the case where difference calculation section 105 calculates difference vectors corresponding to 1 symbol, but calculating difference vectors between 2 symbols doubles the amount of variation of difference vector 114 corresponding to the frequency. Because of this, when

the CNR is sufficient and it is desired to improve the frequency accuracy, it is recommended to increase calculation symbol intervals.

Furthermore, this embodiment describes the method of estimating corresponding known signal 112 and the time during which known signal 112 exists from the peak position of correlation signal 116, but correlation signal 116 has various other characteristics and can also be used to estimate a multipath environment by detecting a plurality of peaks, for example.

Furthermore, this embodiment describes the case of 1 sample per 1 symbol, but the present invention can also be implemented in the case of 4 samples per 1 symbol by setting a time step of addition difference signal 115 to 1/4 (t+0, t+1/4, t+2/4, t+3/4, t+1, t+5/4, ⋯). Of course, changing this step otherwise will make the present invention applicable to any samples.

This embodiment describes the case where matched filtering processing is carried out by the convolver, but the present invention is also applicable to a case where matched filtering processing is carried out by a transversal filter or SAW filter.

(Embodiment 4)

This embodiment describes a case where a known signal is changed when convolver 104 performs matched filtering processing and frequency estimation is performed using the detection information output from detection section 108.

FIG.5 is a block diagram showing a configuration of a radio reception apparatus according to Embodiment 4 of the present invention. In FIG.5, the same components as those in FIG.1 are assigned the same

5   reference numerals and detailed explanations thereof will be omitted.

The radio reception apparatus shown in FIG.5 is provided with selection section 201 for selecting known signal 112 output from known signal storage section 103

10 and frequency estimation section 301 for estimating a frequency based on the detection information output from detection section 108. Estimated frequency 302 estimated by frequency estimation section 301 is output. Therefore, the known signal output to known signal

15 delayer 1042 of convolver 104 is selected known signal 202 selected from among known signals stored in known signal storage section 103. Furthermore, frequency estimation section 301 outputs the estimated frequency based on the detected information (detected signal 117).

20   In the radio reception apparatus as configured above, shift register 102 that stores demodulated signal 110 demodulated by reception section 101 outputs s symbols of calculation series length 119 (denoted as "s") given by calculation length determination section 118

25 from the start (time t+0) of the estimation range to reception signal delayer 1041 of convolver 104 as reception signal 111 (here, suppose calculation series length s=4).

Selection section 201 selects one of n types of known signals stored in known signal storage section 103 and outputs s symbols (here, suppose calculation series length s=4) from the start of the selected known signal to known signal delayer 1042 of convolver 104 as selected known signal 202.

Convolver 104 performs matched filtering processing between reception signal 111 and selected known signal 202. That is, convolver 104 multiplies reception signal 111 and selected known signal 202 using their respective multipliers 1043 and adds up their respective multiplication results using adder 1044. Convolver 104 outputs the output of adder 1044 as short-term correlation signal 113 to difference calculation section 105. This short-term correlation signal 113 is recognized as a short-term correlation signal at time (t+0).

Then, shift register 102 outputs 4 symbols from the symbol at time (t+1) when 1 symbol is shifted as reception signal 111 to reception signal delayer 1041 of convolver 104. Known signal storage section 103 outputs 4 symbols from the 2nd symbol of the selected known signal as selected known signal 202 to known signal delayer 1042 of convolver 104.

In the same way as that described above, convolver 104 performs matched filtering processing and outputs short-term correlation signal 113 at time (t+1) to difference calculation section 105. In this way,

short-term correlation signals 113 are calculated from time (t+0) to time (t+N-4) (N is the signal length of the known signal series).

Calculated short-term correlation signal 113 is sequentially output to difference calculation section 105 and difference calculation section 105 calculates difference vectors corresponding to 1 symbol of short-term correlation signal 113. That is, delayer 1051 delays short-term correlation signal 113 by 1 symbol, complex conjugate section 1052 acquires a complex conjugate of the short-term correlation signal and multiplier 1053 multiplies short-term correlation signal 113 by the complex conjugate of short-term correlation signal 113 delayed by 1 symbol. This calculation result is output as correlation difference signal 114 to addition section 106.

Correlation difference signal 114 obtained in this way is calculated for 1 series of selected known signals 202. Addition section 106 adds up correlation difference signal 114 and outputs the addition result as addition difference signal 115 at time (t+0) to memory 107.

Likewise, addition difference signal 115 at time (t+1) by replacing t with t+1 is calculated. Thus, addition difference signals 115 from time (t+0) to time (t+M-1) are stored in memory 107.

When the calculation of the first known signal series is completed, selection section 201 selects a

second known signal series and carries out the above processing. The selection section 201 continues the above processing until the calculation of all (or some of) known signal series is completed.

5   At this time, storing the storage location, the type of the known signal series and time information corresponding to addition difference signal 115 in memory 107 according to, for example, a rule that the storage location = (known signal series information, time information) makes it easier to extract the known signal series and time information from detection section 108, which will be described later.

Detection section 108 sequentially calculates the size of the vector series of correlation signals 116 output from memory 107, searches correlation signal 116 of the maximum size, finds the size, storage location, the corresponding known signal series and its vector information and outputs this detected information as detected signal 117.

20   At this time, the size of correlation signal 116 generally expresses a correlation value between reception signal 101 and known signal 112 to be searched. The greater this value, the more certain this information can be. Next, the storage location shows a strong correlation with the time information as described above, and therefore it is easy to convert the storage location to the time information. The time information at this time indicates that known signal 112 to be searched is

within the detected time of reception signal 101. Because of this, in a system in which sync signals of a plurality of types are inserted in a specific location of burst, it is possible to detect the type and location

5   of a sync signal in demodulated signal 110 by regarding this sync signal as known signal 112 and the reception burst signal as demodulated signal 110 and thereby establish synchronization with the system.

Furthermore, by detection section 108 detecting m

10   peak positions and vectors from the maximum value of correlation signal 116, it is also possible to estimate a multipath condition that occurs due to differences in the propagation path.

Furthermore, this correlation signal 116 performs

15   a convolution calculation between reception signal 111 and known signal 112, removes the information component and uses the difference vector, and in this way the vector angle includes a frequency component. Frequency estimation section 301 detects the frequency component

20   from detected signal 117 output from detection section 108 and outputs estimated frequency 302. This estimated frequency 302 can be generally used as a frequency shift between the transmitter and receiver and estimated frequency 302 can also be used as the control signal of

25   frequency control, for example.

This embodiment describes the case where calculation series length 119 (s) given by calculation series length 118 is 4, but the present invention is also

applicable to a case where calculation series length s is not 4. The greater the calculation series length, greater the effect of averaging of noise is. For example, an improvement to the characteristic by averaging is

5 expected by setting s=4, thus drastically alleviating the reception environment condition for establishing synchronization and offering prospects of great effects especially in a harsh CNR environment. On the other hand, since the phase is shifted for every symbol due to

10 influences of frequency shifts, increasing calculation series length s will make the system more susceptible to frequency shifts, etc.

For this reason, whether or not to increase calculation series length s up to a size equivalent to

15 the known signal series length should be considered according to the situation as appropriate. The optimal value of this calculation series length s depends on conditions such as the symbol rate, frequency accuracy and system design. In general, the frequency accuracy

20 is sufficiently high with respect to the symbol rate, and therefore problems are not likely to occur if s is set within the range of 4 to 6.

This embodiment describes the case where difference calculation section 105 calculates

25 difference vectors corresponding to 1 symbol, but calculating difference vectors between 2 symbols doubles the amount of variation of difference vector 114 corresponding to the frequency. Because of this, when

the CNR is sufficient and it is desired to improve the frequency accuracy, it is recommended to increase calculation symbol intervals.

Furthermore, this embodiment describes the method
5   of estimating corresponding known signal 112 and the time during which known signal 112 exists from the peak position of correlation signal 116, but correlation signal 116 has various other characteristics and can also be used to estimate a multipath environment by detecting
10   a plurality of peaks, for example.

Furthermore, this embodiment describes the case of 1 sample per 1 symbol, but the present invention can also be implemented in the case of 4 samples per 1 symbol by setting a time step of addition difference signal 115
15   to 1/4 (t+0, t+1/4, t+2/4, t+3/4, t+1, t+5/4, ⋯). Of course, changing this step otherwise will make the present invention applicable to any samples.

(Embodiment 5)

This embodiment describes a case where power is
20   calculated using addition difference signal 115, which is the output of addition section 106.

FIG.6 is a block diagram showing a configuration of a radio reception apparatus according to Embodiment 5 of the present invention. In FIG.6, the same
25   components as those in FIG.1 are assigned the same reference numerals and detailed explanations thereof will be omitted.

The radio reception apparatus shown in FIG.6 is

provided with power calculation section 401 for
calculating power using addition difference signal 115,
which is the output of addition section 106. Therefore,
power signal 402 obtained by power calculation section

5   401 is output to memory 107.

In the radio reception apparatus as configured
above, shift register 102 that stores demodulated signal
110 demodulated by reception section 101 outputs s
symbols of calculation series length 119 (denoted as "s")

10 given by calculation length determination section 118
from the start (time t+0) of the estimation range to
reception signal delayer 1041 of convolver 104 as
reception signal 111 (here, suppose calculation series
length s=4).

15 Known signal storage section 103 outputs s symbols
(here, suppose calculation series length s=4) from the
start of the known signal to known signal delayer 1042
of convolver 104 as known signal 112.

Convolver 104 performs matched filtering

20 processing between reception signal 111 and known signal
112. That is, convolver 104 multiplies reception signal
111 by known signal 112 using their respective
multipliers 1043 and adds up their respective
multiplication results using adder 1044. Convolver 104

25 outputs the output of adder 1044 as short-term
correlation signal 113 to difference calculation section
105. This short-term correlation signal 113 is
recognized as a short-term correlation signal at time

(t+0).

Then, shift register 102 outputs 4 symbols from the symbol at time (t+1) when 1 symbol is shifted as reception signal 111 to reception signal delayer 1041 of convolver

5   104. Known signal storage section 103 outputs 4 symbols from the 2nd symbol of the known signal as known signal 112 to known signal delayer 1042 of convolver 104.

In the same way as that described above, convolver 104 performs matched filtering processing and outputs

10 short-term correlation signal 113 at time (t+1) to difference calculation section 105. In this way, short-term correlation signals 113 are calculated from time (t+0) to time (t+N-4) (N is the signal length of the known signal series).

15 Calculated short-term correlation signal 113 is sequentially output to difference calculation section 105 and difference calculation section 105 calculates difference vectors corresponding to 1 symbol of short-term correlation signal 113. That is, delayer

20 1051 delays short-term correlation signal 113 by 1 symbol, complex conjugate section 1052 acquires a complex conjugate of the short-term correlation signal and multiplier 1053 multiplies short-term correlation signal 113 by the complex conjugate of short-term

25 correlation signal 113 delayed by 1 symbol. This calculation result is output as correlation difference signal 114 to addition section 106.

Correlation difference signal 114 obtained in this

way is calculated for 1 series of selected known signals 202. Addition section 106 adds up correlation difference signal 114 and outputs the addition result as addition difference signal 115 at time (t+0) to power calculation section 401.

Likewise, addition difference signal 115 at time (t+1) by replacing t with t+1 is calculated. Thus, addition difference signal 115 from time (t+0) to time (t+M-1) is output to power calculation section 401 and power calculation section 401 calculates a vector power value using addition difference signal 115 and outputs the calculation result to memory 107 as power signal 402.

At this time, storing the storage location and time information corresponding to power signal 402 in memory 107 according to, for example, a rule that the storage location = time information makes it easier to extract the known signal series and time information from detection section 108, which will be described later.

Detection section 108 sequentially calculates the size of the vector series of correlation signals 116 output from memory 107, searches correlation signal 116 of the maximum size, finds the size, storage location, and its vector information and outputs this detected information as detected signal 117.

At this time, the size of correlation signal 116 generally expresses a correlation value between reception signal 101 and known signal 112 to be searched. The greater this value, the more certain this information

can be. Next, the storage location shows a strong
correlation with the time information as described above,
and therefore it is easy to convert the storage location
to the time information. The time information at this

5   time indicates that known signal 112 to be searched is
within the detected time of reception signal 101.
Because of this, in a system in which sync signals of
a plurality of types are inserted in a specific location
of burst, it is possible to detect the type and location

10 of a sync signal in demodulated signal 110 by regarding
this sync signal as known signal 112 and the reception
burst signal as demodulated signal 110 and thereby
establish synchronization with the system.

       Furthermore, by detection section 108 detecting m

15 peak positions and vectors from the maximum value of
correlation signal 116, it is also possible to estimate
a multipath condition that occurs due to differences in
the propagation path.

       This embodiment describes the case where

20 calculation series length 119 (s) given by calculation
series length 118 is 4, but the present invention is also
applicable to a case where calculation series length s
is not 4. The greater the calculation series length,
greater the effect of averaging of noise is. For example,

25 an improvement to the characteristic by averaging is
expected by setting s=4, thus drastically alleviating
the reception environment condition for establishing
synchronization and offering prospects of great effects

especially in a harsh CNR environment. On the other hand, since the phase is shifted for every symbol due to influences of frequency shifts, increasing calculation series length s will make the system more susceptible

5   to frequency shifts, etc.

For this reason, whether or not to increase calculation series length s up to a size equivalent to the known signal series length should be considered according to the situation as appropriate. The optimal

10   value of this calculation series length s depends on conditions such as the symbol rate, frequency accuracy and system design. In general, the frequency accuracy is sufficiently high with respect to the symbol rate, and therefore problems are not likely to occur if s is

15   set within the range of 4 to 6.

Furthermore, this embodiment describes the method of estimating corresponding known signal 112 and the time during which known signal 112 exists from the peak position of correlation signal 116, but correlation

20   signal 116 has various other characteristics and can also be used to estimate a multipath environment by detecting a plurality of peaks, for example.

This embodiment uses a vector power value as the information stored in memory 107, and thus is

25   characterized in that if the vector value is information consisting of two elements such as (x,y), it is possible to reduce the capacity required for memory 107 to 1/2. Therefore, the reduction effect improves as the number

of elements increases.

Furthermore, this embodiment describes the case of 1 sample per 1 symbol, but the present invention can also be implemented in the case of 4 samples per 1 symbol by

5   setting a time step of addition difference signal 115 to 1/4 (t+0, t+1/4, t+2/4, t+3/4, t+1, t+5/4, ⋯). Of course, changing this step otherwise will make the present invention applicable to any samples.

This embodiment describes the case where matched

10 filtering processing is carried out by a convolver, but the present invention is also applicable to a case where matched filtering processing is carried out by a transversal filter or SAW filter.

(Embodiment 6)

15 This embodiment describes a case where a known signal is changed when convolver 104 performs matched filtering processing and power is calculated using addition difference signal 115, which is the output of addition section 106.

20 FIG.7 is a block diagram showing a configuration of a radio reception apparatus according to Embodiment 6 of the present invention. In FIG.7, the same components as those in FIG.1 are assigned the same reference numerals and detailed explanations thereof

25 will be omitted.

The radio reception apparatus shown in FIG.7 is provided with selection section 201 for selecting known signal 112 output from known signal storage section 103

and power calculation section 401 for calculating power using addition difference signal 115, which is the output of addition section 106. Therefore, the known signal output to known signal delayer 1042 of convolver 104 is

5   selected known signal 202 selected from among known signals stored in known signal storage section 103. Furthermore, power signal 402 obtained by power calculation section 401 is output to memory 107.

In the radio reception apparatus as configured

10   above, shift register 102 that stores demodulated signal 110 demodulated by reception section 101 outputs s symbols of calculation series length 119 (denoted as "s") given by calculation length determination section 118 from the start (time t+0) of the estimation range to

15   reception signal delayer 1041 of convolver 104 as reception signal 111 (here, suppose calculation series length s=4).

Selection section 201 selects one of n types of known signals stored in known signal storage section 103

20   and outputs s symbols (here, suppose calculation series length s=4) from the start of the selected known signal to known signal delayer 1042 of convolver 104 as selected known signal 202.

Convolver 104 performs matched filtering

25   processing between reception signal 111 and selected known signal 202. That is, convolver 104 multiplies reception signal 111 and selected known signal 202 using their respective multipliers 1043 and adds up their

respective multiplication results using adder 1044.
Convolver 104 outputs the output of adder 1044 as
short-term correlation signal 113 to difference
calculation section 105. This short-term correlation
5   signal 113 is recognized as a short-term correlation
signal at time (t+0).

Then, shift register 102 outputs 4 symbols from the
symbol at time (t+1) when 1 symbol is shifted as reception
signal 111 to reception signal delayer 1041 of convolver
10   104. Known signal storage section 103 outputs 4 symbols
from the 2nd symbol of the selected known signal as
selected known signal 202 to known signal delayer 1042
of convolver 104.

In the same way as that described above, convolver
15   104 performs matched filtering processing and outputs
short-term correlation signal 113 at time (t+1) to
difference calculation section 105. In this way,
short-term correlation signals 113 are calculated from
time (t+0) to time (t+N-4) (N is the signal length of
20   the known signal series).

Calculated short-term correlation signal 113 is
sequentially output to difference calculation section
105 and difference calculation section 105 calculates
difference vectors corresponding to 1 symbol of
25   short-term correlation signal 113. That is, delayer
1051 delays short-term correlation signal 113 by 1 symbol,
complex conjugate section 1052 acquires a complex
conjugate of the short-term correlation signal and

multiplier 1053 multiplies short-term correlation signal 113 by the complex conjugate of short-term correlation signal 113 delayed by 1 symbol. This calculation result is output as correlation difference

5   signal 114 to addition section 106.

    Correlation difference signal 114 obtained in this way is calculated for 1 series of selected known signals 202. Addition section 106 adds up correlation difference signal 114 and outputs the addition result

10 as addition difference signal 115 at time (t+0) to power calculation section 401.

    Likewise, addition difference signal 115 at time (t+1) by replacing t with t+1 is calculated. Thus, addition difference signal 115 from time (t+0) to time

15 (t+M-1) is output to power calculation section 401 and power calculation section 401 calculates a vector power value using addition difference signal 115 and outputs the calculation result to memory 107 as power signal 402.

    When the calculation of the first known signal

20 series is completed, selection section 201 selects a second known signal series and carries out the above processing. The selection section 201 continues the above processing until the calculation of all (or some of) known signal series is completed.

25 At this time, storing the storage location, the type of a series of known signals and time information corresponding to power signal 402 in memory 107 according to, for example, a rule that the storage location = (known

signal series information, time information) makes it easier to extract the known signal series and time information from detection section 108, which will be described later.

5   Detection section 108 sequentially calculates the size of the vector series of correlation signals 116 output from memory 107, searches correlation signal 116 of the maximum size, finds the size, storage location, the corresponding known signal series and its vector

10   information and outputs this detected information as detected signal 117.

At this time, the size of correlation signal 116 generally expresses a correlation value between reception signal 101 and known signal 112 to be searched.

15   The greater this value, the more certain this information can be. Next, the storage location shows a strong correlation with the time information as described above, and therefore it is easy to convert the storage location to the time information. The time information at this

20   time indicates that known signal 112 to be searched is within the detected time of reception signal 101. Because of this, in a system in which sync signals of a plurality of types are inserted in a specific location of burst, it is possible to detect the type and location

25   of a sync signal in demodulated signal 110 by regarding this sync signal as known signal 112 and the reception burst signal as demodulated signal 110 and thereby establish synchronization with the system.

Furthermore, by detection section 108 detecting m peak positions and vectors from the maximum value of correlation signal 116, it is also possible to estimate a multipath condition that occurs due to differences in 5 the propagation path.

This embodiment describes the case where calculation series length 119 (s) given by calculation series length 118 is 4, but the present invention is also applicable to a case where calculation series length s 10 is not 4. The greater the calculation series length, greater the effect of averaging of noise is. For example, an improvement to the characteristic by averaging is expected by setting s=4, thus drastically alleviating the reception environment condition for establishing 15 synchronization and offering prospects of great effects especially in a harsh CNR environment. On the other hand, since the phase is shifted for every symbol due to influences of frequency shifts, increasing calculation series length s will make the system more susceptible 20 to frequency shifts, etc.

For this reason, whether or not to increase calculation series length s up to a size equivalent to the known signal series length should be considered according to the situation as appropriate. The optimal 25 value of this calculation series length s depends on conditions such as the symbol rate, frequency accuracy and system design. In general, the frequency accuracy is sufficiently high with respect to the symbol rate,

and therefore problems are not likely to occur if s is
set within the range of 4 to 6.

Furthermore, this embodiment describes the method
of estimating corresponding known signal 112 and the time

5   during which known signal 112 exists from the peak
position of correlation signal 116, but correlation
signal 116 has various other characteristics and can also
be used to estimate a multipath environment by detecting
a plurality of peaks, for example.

10   This embodiment uses a vector power value as the
information stored in memory 107, and thus is
characterized in that if the vector value is information
consisting of two elements such as (x,y), it is possible
to reduce the capacity required for memory 107 to 1/2.

15   Therefore, the reduction effect improves as the number
of elements increases.

Furthermore, this embodiment describes the case of
1 sample per 1 symbol, but the present invention can also
be implemented in the case of 4 samples per 1 symbol by

20   setting a time step of addition difference signal 115
to 1/4 (t+0, t+1/4, t+2/4, t+3/4, t+1, t+5/4, ⋯). Of
course, changing this step otherwise will make the
present invention applicable to any samples.
(Embodiment 7)

25   This embodiment describes a case where the
calculation series length is controlled according to the
reception situation.

FIG.8 is a block diagram showing a configuration

of a radio reception apparatus according to Embodiment 7 of the present invention. In FIG.8, the same components as those in FIG.1 are assigned the same reference numerals and detailed explanations thereof will be omitted.

The radio reception apparatus shown in FIG.8 is provided with reception situation estimation section 501 that estimates the reception situation from a reception signal and calculation length control section 503 for controlling the calculation series length based on the reception situation. Therefore, the calculation series length is determined according to the reception situation estimated by reception situation estimation section 501 and the calculation series length is output to known signal delayer 1042 of convolver 104. Convolver 104 performs matched filtering processing with the determined calculation series length.

In the radio reception apparatus as configured above, shift register 102 that stores demodulated signal 110 demodulated by reception section 101 outputs s symbols of calculation series length 119 (denoted as "s") controlled by calculation length control section 501 from the start (time t+0) of the estimation range to reception signal delayer 1041 of convolver 104 as reception signal 111 (here, suppose calculation series length s=4).

Known signal storage section 103 outputs s symbols (here, suppose calculation series length s = 4) from a

known signal as known signal 112 to known signal delayer 1042 of convolver 104.

Reception situation estimation section 501 estimates its CNR using demodulated signal 110 and
5   outputs the estimation result to calculation length control section 503 as estimated reception situation 502. Calculation length control section 503 controls the calculation series length according to estimated reception situation 502. For example, calculation
10   length control section 503 controls calculation series length 119 (s) to a large value if the CNR is good and controls calculation series length 119 (s) to a small value if the CNR is bad.

Convolver 104 performs matched filtering
15   processing between reception signal 111 and known signal 112. That is, convolver 104 multiplies reception signal 111 by known signal 112 using their respective multipliers 1043 and adds up their respective multiplication results using adder 1044. Convolver 104
20   outputs the output of adder 1044 as short-term correlation signal 113 to difference calculation section 105. This short-term correlation signal 113 is recognized as a short-term correlation signal at time (t+0).

25   Then, shift register 102 outputs 4 symbols from the symbol at time (t+1) when 1 symbol is shifted as reception signal 111 to reception signal delayer 1041 of convolver 104. Known signal storage section 103 outputs 4 symbols

from the 2nd symbol of the selected known signal as known signal 112 to known signal delayer 1042 of convolver 104.

In the same way as that described above, convolver 104 performs matched filtering processing and outputs

5   short-term correlation signal 113 at time (t+1) to difference calculation section 105. In this way, short-term correlation signals 113 are calculated from time (t+0) to time (t+N-4) (N is the signal length of the known signal series).

10   Calculated short-term correlation signal 113 is sequentially output to difference calculation section 105 and difference calculation section 105 calculates difference vectors corresponding to 1 symbol of short-term correlation signal 113. That is, delayer

15   1051 delays short-term correlation signal 113 by 1 symbol, complex conjugate section 1052 acquires a complex conjugate of the short-term correlation signal and multiplier 1053 multiplies short-term correlation signal 113 by the complex conjugate of short-term correlation signal 113 delayed by 1 symbol. This

20   calculation result is output as correlation difference signal 114 to addition section 106.

Correlation difference signal 114 obtained in this way is calculated for 1 series of known signals 112.

25   Addition section 106 adds up correlation difference signal 114 and outputs the addition result as addition difference signal 115 at time (t+0) to memory 107.

Likewise, addition difference signal 115 at time

(t+1) by replacing t with t+1 is calculated. Thus, addition difference signal 115 from time (t+0) to time (t+M-1) is stored in memory 107.

At this time, storing the storage location and time information corresponding to addition difference signal 115 in memory 107 according to, for example, a rule that the storage location = time information makes it easier to extract the known signal series and time information from detection section 108, which will be described later.

Detection section 108 sequentially calculates the size of the vector series of correlation signals 116 output from memory 107, searches correlation signal 116 of the maximum size, finds the size, storage location and its vector information and outputs this detected information as detected signal 117.

At this time, the size of correlation signal 116 generally expresses a correlation value between reception signal 101 and known signal 112 to be searched. The greater this value, the more certain this information can be. Next, the storage location shows a strong correlation with the time information as described above, and therefore it is easy to convert the storage location to the time information. The time information at this time indicates that known signal 112 to be searched is within the detected time of reception signal 101. Because of this, in a system in which sync signals of a plurality of types are inserted in a specific location

of burst, it is possible to detect the type and location of a sync signal in demodulated signal 110 by regarding this sync signal as known signal 112 and the reception burst signal as demodulated signal 110 and thereby

5   establish synchronization with the system.

Furthermore, by detection section 108 detecting m peak positions and vectors from the maximum value of correlation signal 116, it is also possible to estimate a multipath condition that occurs due to differences in

10   the propagation path.

This embodiment describes the case where calculation series length 119 (s) given by calculation series length 118 is 4, but the present invention is also applicable to a case where calculation series length s

15   is not 4. Calculation series length s is a value controlled by calculation length control section 503 and is variable as described above. Regarding control of calculation series length s, the case where CNR of demodulated signal 110 is estimated is shown as an

20   example, but it is also possible to use parameters other than CNR, for example, reception power, reception quality (quality factor such as Eb/No). The greater the calculation series length s, the greater the effect of averaging noise is.

25   For this reason, if estimated reception situation 502 of reception situation estimation section 501 is good, reducing the value of calculation series length s can also simplify the calculation. Furthermore, the

presence of a frequency shift causes the phase to be
shifted for every symbol as its influence and an error
is produced when calculation series length s is set to
a large value. For this reason, equalizing the size of
5   calculation series length s to the size of the known
signal series length may not be desirable. The optimal
value of this calculation series length s depends on
conditions such as the symbol rate, frequency accuracy
and system design. In general, the frequency accuracy
10   is sufficiently high with respect to the symbol rate,
and therefore problems are not likely to occur if s is
set within the range of 4 to 6.

Furthermore, this embodiment describes the method
of estimating corresponding known signal 112 and the time
15   during which known signal 112 exists from the peak
position of correlation signal 116, but correlation
signal 116 has various other characteristics and can also
be used to estimate a multipath environment by detecting
a plurality of peaks, for example.

20   Furthermore, this embodiment describes the case of
1 sample per 1 symbol, but the present invention can also
be implemented in the case of 4 samples per 1 symbol by
setting a time step of addition difference signal 115
to 1/4 (t+0, t+1/4, t+2/4, t+3/4, t+1, t+5/4, ⋯). Of
25   course, changing this step otherwise will make the
present invention applicable to any samples.

The calculation series length s may be controlled
to change corresponding to the number of times the

synchronization timing is detected.

This embodiment describes the case where matched filtering processing is carried out by the convolver, but the present invention is also applicable to a case where matched filtering processing is carried out by a transversal filter or SAW filter.

(Embodiment 8)

This embodiment describes a case where a known signal is changed when convolver 104 performs matched filtering processing and the calculation series length is controlled according to the reception situation.

FIG.9 is a block diagram showing a configuration of a radio reception apparatus according to Embodiment 8 of the present invention. In FIG.9, the same components as those in FIG.1 are assigned the same reference numerals and detailed explanations thereof will be omitted.

The radio reception apparatus shown in FIG.9 is provided with selection section 201 for selecting known signal 112 output from known signal storage section 103, reception situation estimation section 501 that estimates the reception situation from a reception signal and calculation length control section 503 for controlling the calculation series length based on the reception situation. Therefore, the known signal output to known signal delayer 1042 of convolver 104 is selected known signal 202 selected from known signals stored in known signal storage section 103. The

calculation series length is determined according to the reception situation estimated by reception situation estimation section 501 and the calculation series length is output to known signal delayer 1042 of convolver 104.

5   Convolver 104 performs matched filtering processing with the determined calculation series length.

In the radio reception apparatus as configured above, shift register 102 that stores demodulated signal 110 demodulated by reception section 101 outputs s

10 symbols of calculation series length 119 (denoted as "s") controlled by calculation length control section 501 from the start (time t+0) of the estimation range to reception signal delayer 1041 of convolver 104 as reception signal 111 (here, suppose calculation series

15 length s=4).

Selection section 201 selects one of n types of known signals stored in known signal storage section 103 and outputs s symbols (here, suppose calculation series length s=4) from the start of the selected known signal

20 to known signal delayer 1042 of convolver 104 as selected known signal 202.

Reception situation estimation section 501 estimates its CNR using demodulated signal 110 and outputs the estimation result to calculation length

25 control section 503 as estimated reception situation 502. Calculation length control section 503 controls the calculation series length according to estimated reception situation 502. For example, calculation

length control section 503 controls calculation series length 119 (s) to a large value if the CNR is good and controls calculation series length 119 (s) to a small value if the CNR is bad.

5   Convolver 104 performs matched filtering processing between reception signal 111 and selected known signal 202. That is, convolver 104 multiplies reception signal 111 by selected known signal 202 using their respective multipliers 1043 and adds up their

10   respective multiplication results using adder 1044. Convolver 104 outputs the output of adder 1044 as short-term correlation signal 113 to difference calculation section 105. This short-term correlation signal 113 is recognized as a short-term correlation

15   signal at time (t+0).

Then, shift register 102 outputs 4 symbols from the symbol at time (t+1) when 1 symbol is shifted as reception signal 111 to reception signal delayer 1041 of convolver 104. Known signal storage section 103 outputs 4 symbols

20   from the 2nd symbol of the selected known signal as selected known signal 202 to known signal delayer 1042 of convolver 104.

In the same way as that described above, convolver 104 performs matched filtering processing and outputs

25   short-term correlation signal 113 at time (t+1) to difference calculation section 105. In this way, short-term correlation signals 113 are calculated from time (t+0) to time (t+N-4) (N is the signal length of

the known signal series).

Calculated short-term correlation signal 113 is sequentially output to difference calculation section 105 and difference calculation section 105 calculates

5   difference vectors corresponding to 1 symbol of short-term correlation signal 113. That is, delayer 1051 delays short-term correlation signal 113 by 1 symbol, complex conjugate section 1052 acquires a complex conjugate of the short-term correlation signal and

10   multiplier 1053 multiplies short-term correlation signal 113 by the complex conjugate of short-term correlation signal 113 delayed by 1 symbol. This calculation result is output as correlation difference signal 114 to addition section 106.

15   Correlation difference signal 114 obtained in this way is calculated for 1 series of selected known signals 202. Addition section 106 adds up correlation difference signal 114 and outputs the addition result as addition difference signal 115 at time (t+0) to memory

20   107.

Likewise, addition difference signal 115 at time (t+1) by replacing t with t+1 is calculated. Thus, addition difference signal 115 from time (t+0) to time (t+M-1) is stored in memory 107.

25   When the calculation of the first known signal series is completed, selection section 201 selects a second known signal series and carries out the above processing. The selection section 201 continues the

above processing until the calculation of all (or some
of) known signal series is completed.

At this time, storing the storage location, the type
of a series of known signals and time information
corresponding to addition difference signal 115 in
memory 107 according to, for example, a rule that the
storage location = (known signal series information,
time information) makes it easier to extract the known
signal series and time information from detection
section 108, which will be described later.

Detection section 108 sequentially calculates the
size of the vector series of correlation signals 116
output from memory 107, searches correlation signal 116
of the maximum size, finds the size, storage location,
the corresponding known signal series and its vector
information and outputs this detected information as
detected signal 117.

At this time, the size of correlation signal 116
generally expresses a correlation value between
reception signal 101 and known signal 112 to be searched.
The greater this value, the more certain this information
can be. Next, the storage location shows a strong
correlation with the time information as described above,
and therefore it is easy to convert the storage location
to the time information. The time information at this
time indicates that known signal 112 to be searched is
within the detected time of reception signal 101.
Because of this, in a system in which sync signals of

a plurality of types are inserted in a specific location of burst, it is possible to detect the type and location of a sync signal in demodulated signal 110 by regarding this sync signal as known signal 112 and the reception

5   burst signal as demodulated signal 110 and thereby establish synchronization with the system.

Furthermore, by detection section 108 detecting m peak positions and vectors from the maximum value of correlation signal 116, it is also possible to estimate

10   a multipath condition that occurs due to differences in the propagation path.

This embodiment describes the case where calculation series length 119 (s) given by calculation series length 118 is 4, but the present invention is also

15   applicable to a case where calculation series length s is not 4. Calculation series length s is a value controlled by calculation length control section 503 and is variable as described before. Regarding control of calculation series length s, the case where CNR of

20   demodulated signal 110 is estimated is shown as an example, but it is also possible to use parameters other than CNR, for example, reception power, reception quality (quality factor such as Eb/No). The greater the calculation series length s, the greater the effect of

25   averaging noise is.

For this reason, if estimated reception situation 502 of reception situation estimation section 501 is good, reducing the value of calculation series length s can

also simplify the calculation. For example, an improvement to the characteristic by averaging is expected by setting s=4, thus drastically alleviating the reception environment condition for establishing synchronization and offering prospects of great effects especially in a harsh CNR environment.

Furthermore, the presence of a frequency shift causes the phase to be shifted for every symbol as its influence and an error is produced when calculation series length s is set to a large value. For this reason, equalizing the size of calculation series length s to the size of the known signal series length may not be desirable. The optimal value of this calculation series length s depends on conditions such as the symbol rate, frequency accuracy and system design. In general, the frequency accuracy is sufficiently high with respect to the symbol rate, and therefore problems are not likely to occur if s is set within the range of 4 to 6.

Furthermore, this embodiment describes the method of estimating corresponding known signal 112 and the time during which known signal 112 exists from the peak position of correlation signal 116, but correlation signal 116 has various other characteristics and can also be used to estimate a multipath environment by detecting a plurality of peaks, for example.

Furthermore, this embodiment describes the case of 1 sample per 1 symbol, but the present invention can also be implemented in the case of 4 samples per 1 symbol by

setting a time step of addition difference signal 115
to 1/4 (t+0, t+1/4, t+2/4, t+3/4, t+1, t+5/4, ⋯). Of
course, changing this step otherwise will make the
present invention applicable to any samples.

5 (Embodiment 9)

This embodiment describes a case where frequency
estimation is performed using the detected information
output from detection section 108 and the calculation
series length is controlled based on the estimated
10 frequency.

FIG.10 is a block diagram showing a configuration
of a radio reception apparatus according to Embodiment
9 of the present invention. In FIG.10, the same
components as those in FIG.1 are assigned the same
15 reference numerals and detailed explanations thereof
will be omitted.

The radio reception apparatus shown in FIG.10 is
provided with frequency estimation section 301 for
estimating a frequency based on the detection
20 information output from detection section 108 and
calculation length control section 503 for controlling
the calculation series length according to the output
of frequency estimation section 301.

In the radio reception apparatus as configured
25 above, calculation length control section 503 controls
the calculation series length according to estimated
frequency 302. For example, calculation length control
section 503 controls calculation series length 119 (s)

to a large value when estimated frequency 302 is close to a target frequency and controls calculation series length 119 (s) to a small value when the error from the target frequency is large.

5   Shift register 102 that stores demodulated signal 110 demodulated by reception section 101 outputs s symbols of calculation series length 119 (denoted as "s") given by calculation length determination section 118 from the start (time t+0) of the estimation range to

10   reception signal delayer 1041 of convolver 104 as reception signal 111 (here, suppose calculation series length s=4).

Known signal storage section 103 outputs s symbols (here, suppose calculation series length s=4) from the

15   start of the known signal to known signal delayer 1042 of convolver 104 as known signal 112.

Convolver 104 performs matched filtering processing between reception signal 111 and known signal 112. That is, convolver 104 multiplies reception signal

20   111 by known signal 112 using their respective multipliers 1043 and adds up their respective multiplication results using adder 1044. Convolver 104 outputs the output of adder 1044 as short-term correlation signal 113 to difference calculation section

25   105. This short-term correlation signal 113 is recognized as a short-term correlation signal at time (t+0).

Then, shift register 102 outputs 4 symbols from the

symbol at time (t+1) when 1 symbol is shifted as reception signal 111 to reception signal delayer 1041 of convolver 104. Known signal storage section 103 outputs 4 symbols from the 2nd symbol of the known signal as known signal

5   112 to known signal delayer 1042 of convolver 104.

In the same way as that described above, convolver 104 performs matched filtering processing and outputs short-term correlation signal 113 at time (t+1) to difference calculation section 105. In this way,

10   short-term correlation signals 113 are calculated from time (t+0) to time (t+N-4) (N is the signal length of the known signal series).

Calculated short-term correlation signal 113 is sequentially output to difference calculation section

15   105 and difference calculation section 105 calculates difference vectors corresponding to 1 symbol of short-term correlation signal 113. That is, delayer 1051 delays short-term correlation signal 113 by 1 symbol, complex conjugate section 1052 acquires a complex

20   conjugate of the short-term correlation signal and multiplier 1053 multiplies short-term correlation signal 113 by the complex conjugate of short-term correlation signal 113 delayed by 1 symbol. This calculation result is output as correlation difference

25   signal 114 to addition section 106.

Correlation difference signal 114 obtained in this way is calculated for 1 series of known signals 112. Addition section 106 adds up correlation difference

signal 114 and outputs the addition result as addition difference signal 115 at time (t+0) to memory 107.

Likewise, addition difference signal 115 at time (t+1) by replacing t with t+1 is calculated. Thus,

5   addition difference signal 115 from time (t+0) to time (t+M-1) is stored in memory 107. At this time, storing the storage location and time information corresponding to addition difference signal 115 in memory 107 according to, for example, a rule that the storage location = time

10 information makes it easier to extract the known signal series and time information from detection section 108, which will be described later.

Detection section 108 sequentially calculates the size of the vector series of correlation signals 116

15 output from memory 107, searches correlation signal 116 of the maximum size, finds the size, storage location and its vector information and outputs this detected information as detected signal 117.

At this time, the size of correlation signal 116

20 generally expresses a correlation value between reception signal 101 and known signal 112 to be searched. The greater this value, the more certain this information can be. Next, the storage location shows a strong correlation with the time information as described above,

25 and therefore it is easy to convert the storage location to the time information. The time information at this time indicates that known signal 112 to be searched is within the detected time of reception signal 101.

Because of this, in a system in which sync signals of a plurality of types are inserted in a specific location of burst, it is possible to detect the type and location of a sync signal in demodulated signal 110 by regarding

5   this sync signal as known signal 112 and the reception burst signal as demodulated signal 110 and thereby establish synchronization with the system.

Furthermore, by detection section 108 detecting m peak positions and vectors from the maximum value of

10 correlation signal 116, it is also possible to estimate a multipath condition that occurs due to differences in the propagation path.

Furthermore, this correlation signal 116 performs a convolution calculation between reception signal 111

15 and known signal 112, removes the information component and uses the difference vector, and in this way the vector angle includes a frequency component. Frequency estimation section 301 detects the frequency component from detected signal 117 output from detection section

20 108 and outputs estimated frequency 302. This estimated frequency 302 can be generally used as a frequency shift between the transmitter and receiver and estimated frequency 302 can also be used as the control signal of frequency control, for example.

25 This embodiment describes the case where calculation series length 119 (s) given by calculation series length 118 is 4, but the present invention is also applicable to a case where calculation series length s

is not 4. Regarding control of calculation series length s, the case where estimated frequency 302 given by frequency estimation section 301 is used is shown as an example, but it is also possible to use values taking

5 into account parameters other than the estimated frequency, for example, reception power, reception quality (quality factor such as Eb/No). The greater the calculation series length s, the greater the effect of averaging noise is.

10 For this reason, if estimated frequency 302 of frequency estimation section 301 is good (the error from the target value is small or when estimated frequency 302 shows a frequency shift, its absolute value is small), reducing the value of calculation series length s can

15 also simplify the calculation. When frequency estimation section 301 does not output estimated frequency 302 as in the case of the first execution, it is desirable to give an optimal initial value to the system obtained from the frequency error range, symbol

20 rate and sensitivity point CNR, etc.

This embodiment describes the case where difference calculation section 105 calculates difference vectors corresponding to 1 symbol, but calculating difference vectors between 2 symbols doubles

25 the amount of variation of difference vector 114 corresponding to the frequency. Because of this, when the CNR is sufficient and it is desired to improve the frequency accuracy, it is recommended to increase

calculation symbol intervals.

Furthermore, this embodiment describes the method of estimating corresponding known signal 112 and the time during which known signal 112 exists from the peak

5   position of correlation signal 116, but correlation signal 116 has various other characteristics and can also be used to estimate a multipath environment by detecting a plurality of peaks, for example.

Furthermore, this embodiment describes the case of

10 1 sample per 1 symbol, but the present invention can also be implemented in the case of 4 samples per 1 symbol by setting a time step of addition difference signal 115 to 1/4 (t+0, t+1/4, t+2/4, t+3/4, t+1, t+5/4, ···). Of course, changing this step otherwise will make the

15 present invention applicable to any samples.

This embodiment describes the case where matched filtering processing is carried out by the convolver, but the present invention is also applicable to a case where matched filtering processing is carried out by a

20 transversal filter or SAW filter.

(Embodiment 10)

This embodiment describes a case where a known signal is changed when matched filtering processing is performed by convolver 104, frequency estimation is

25 performed using the detection information output from detection section 108 and the calculation series length is controlled based on the estimated frequency.

FIG.11 is a block diagram showing a configuration

of a radio reception apparatus according to Embodiment 10 of the present invention. In FIG.11, the same components as those in FIG.1 are assigned the same reference numerals and detailed explanations thereof

5   will be omitted.

The radio reception apparatus shown in FIG.11 is provided with selection section 201 for selecting known signal 112 output from known signal storage section 103, frequency estimation section 301 for estimating a

10 frequency based on the detected information output from detection section 108 and calculation length control section 503 for controlling the calculation series length according to the output of frequency estimation section 301.

15 In the radio reception apparatus as configured above, calculation length control section 503 controls the calculation series length according to estimated frequency 302. For example, calculation length control section 503 controls calculation series length 119 (s)

20 to a large value when estimated frequency 302 is close to a target frequency and controls calculation series length 119 (s) to a small value when the error from the target frequency is large.

Shift register 102 that stores demodulated signal

25 110 demodulated by reception section 101 outputs s symbols of calculation series length 119 (denoted as "s") given by calculation length determination section 118 from the start (time t+0) of the estimation range to

reception signal delayer 1041 of convolver 104 as
reception signal 111 (here, suppose calculation series
length s=4).

Selection section 201 selects one of n types of
known signals stored in known signal storage section 103
and outputs s symbols (here, suppose calculation series
length s=4) from the start of the selected known signal
to known signal delayer 1042 of convolver 104 as known
signal 112.

Convolver 104 performs matched filtering
processing between reception signal 111 by selected
known signal 202. That is, convolver 104 multiplies
reception signal 111 and selected known signal 202 using
their respective multipliers 1043 and adds up their
respective multiplication results using adder 1044.
Convolver 104 outputs the output of adder 1044 as
short-term correlation signal 113 to difference
calculation section 105. This short-term correlation
signal 113 is recognized as a short-term correlation
signal at time (t+0).

Then, shift register 102 outputs 4 symbols from the
symbol at time (t+1) when 1 symbol is shifted as reception
signal 111 to reception signal delayer 1041 of convolver
104. Known signal storage section 103 outputs 4 symbols
from the 2nd symbol of the selected known signal as
selected known signal 202 to known signal delayer 1042
of convolver 104.

In the same way as that described above, convolver

104 performs matched filtering processing and outputs short-term correlation signal 113 at time (t+1) to difference calculation section 105. In this way, short-term correlation signals 113 are calculated from

5   time (t+0) to time (t+N-4) (N is the signal length of the known signal series).

   Calculated short-term correlation signal 113 is sequentially output to difference calculation section 105 and difference calculation section 105 calculates

10 difference vectors corresponding to 1 symbol of short-term correlation signal 113. That is, delayer 1051 delays short-term correlation signal 113 by 1 symbol, complex conjugate section 1052 acquires a complex conjugate of the short-term correlation signal and

15 multiplier 1053 multiplies short-term correlation signal 113 by the complex conjugate of short-term correlation signal 113 delayed by 1 symbol. This calculation result is output as correlation difference signal 114 to addition section 106.

20   Correlation difference signal 114 obtained in this way is calculated for 1 series of known signals 112. Addition section 106 adds up correlation difference signal 114 and outputs the addition result as addition difference signal 115 at time (t+0) to memory 107.

25   Likewise, addition difference signal 115 at time (t+1) by replacing t with t+1 is calculated. Thus, addition difference signal 115 from time (t+0) to time (t+M-1) is stored in memory 107.

When the calculation of the first known signal series is completed, selection section 201 selects a second known signal series and carries out the above processing. The selection section 201 continues the

5   above processing until the calculation of all (or some of) known signal series is completed.

At this time, storing the storage location, the type of a series of known signals and time information corresponding to addition difference signal 115 in

10   memory 107 according to, for example, a rule that the storage location = (known signal series information, time information) makes it easier to extract the known signal series and time information from detection section 108, which will be described later.

15   Detection section 108 sequentially calculates the size of the vector series of correlation signals 116 output from memory 107, searches correlation signal 116 of the maximum size, finds the size, storage location, the corresponding known signal series and its vector

20   information and outputs this detected information as detected signal 117.

At this time, the size of correlation signal 116 generally expresses a correlation value between reception signal 101 and known signal 112 to be searched.

25   The greater this value, the more certain this information can be. Next, the storage location shows a strong correlation with the time information as described above, and therefore it is easy to convert the storage location

to the time information. The time information at this time indicates that known signal 112 to be searched is within the detected time of reception signal 101. Because of this, in a system in which sync signals of

5   a plurality of types are inserted in a specific location of burst, it is possible to detect the type and location of a sync signal in demodulated signal 110 by regarding this sync signal as known signal 112 and the reception burst signal as demodulated signal 110 and thereby

10   establish synchronization with the system.

Furthermore, by detection section 108 detecting m peak positions and vectors from the maximum value of correlation signal 116, it is also possible to estimate a multipath condition that occurs due to differences in

15   the propagation path.

Furthermore, this correlation signal 116 performs a convolution calculation between reception signal 111 and known signal 112, removes the information component and uses the difference vector, and in this way the vector

20   angle includes a frequency component. Frequency estimation section 301 detects the frequency component from detected signal 117 output from detection section 108 and outputs estimated frequency 302. This estimated frequency 302 can be generally used as a frequency shift

25   between the transmitter and receiver and estimated frequency 302 can also be used as the control signal of frequency control, for example.

This embodiment describes the case where

calculation series length 119 (s) given by calculation series length 118 is 4, but the present invention is also applicable to a case where calculation series length s is not 4. Regarding control of calculation series length

5   s, the case where estimated frequency 302 given by frequency estimation section 301 is used is shown as an example, but it is also possible to use values taking into account parameters other than the estimated frequency, for example, reception power, reception

10 quality (quality factor such as Eb/No). The greater the calculation series length s, the greater the effect of averaging noise is.

    For this reason, if estimated frequency 302 of frequency estimation section 301 is good (the error from

15 the target value is small or when estimated frequency 302 shows a frequency shift, its absolute value is small), reducing the value of calculation series length s can also simplify the calculation. When frequency estimation section 301 does not output estimated

20 frequency 302 as in the case of the first execution, it is desirable to give an optimal initial value to the system obtained from the frequency error range, symbol rate and sensitivity point CNR, etc.

    This embodiment describes the case where

25 difference calculation section 105 calculates difference vectors corresponding to 1 symbol, but calculating difference vectors between 2 symbols doubles the amount of variation of difference vector 114

corresponding to the frequency. Because of this, when the CNR is sufficient and it is desired to improve the frequency accuracy, it is recommended to increase calculation symbol intervals.

Furthermore, this embodiment describes the method of estimating corresponding known signal 112 and the time during which known signal 112 exists from the peak position of correlation signal 116, but correlation signal 116 has various other characteristics and can also be used to estimate a multipath environment by detecting a plurality of peaks, for example.

Furthermore, this embodiment describes the case of 1 sample per 1 symbol, but the present invention can also be implemented in the case of 4 samples per 1 symbol by setting a time step of addition difference signal 115 to 1/4 (t+0, t+1/4, t+2/4, t+3/4, t+1, t+5/4, ···). Of course, changing this step otherwise will make the present invention applicable to any samples.

The present invention is not limited to Embodiments 1 to 10 above, but can be implemented with various modifications. For example, the technologies described in Embodiments 1 to 10 above can be implemented, combined with one another as appropriate.

Furthermore, Embodiments 1 to 10 above describe the cases where the radio reception apparatus is mounted on a communication terminal apparatus, but the present invention is also applicable to a case where the radio reception apparatus of the present invention is mounted

on a radio base station apparatus.

The radio reception apparatus of the present invention comprises a shift register for storing a series of reception signals, a known signal storage section for storing a series of known signals, a calculation length determination section for determining a calculation series length, a convolver for calculating convolution integration between symbol number s given by the calculation length determination section from a series of known signals sequentially output from the known signal storage section and a series of signals corresponding to s symbols selected at symbol intervals from the reception signal series, a difference calculation section for calculating difference vectors corresponding to 1 symbol of the signal series subjected to convolution integration, an addition section for sequentially adding up the difference vectors, memory for calculating addition difference vectors in the same way by shifting the reception signal series by 1 sample at a time and storing the time of shifting in association with the addition difference vectors and a detection section for detecting parts that satisfy a specific condition from the vectors stored in the memory.

This configuration makes it possible to detect a target known signal series from the reception signal and detect the reception time of the known signal series with stable performance from the reception signal series received in a harsh environment of signal to noise ratio

(CNR).

The radio reception apparatus of the present invention comprises a shift register for storing a series of reception signals, a known signal storage section for storing a series of n (n: natural number of 2 or above) known signals, a calculation length determination section for determining a calculation series length, a switching section for switching between known signal series, a convolver for calculating convolution integration between symbol number s given by the calculation length determination section from a series of known signals sequentially output from the known signal storage section and a series of signals corresponding to s symbols selected at symbol intervals from the reception signal series, a difference calculation section for calculating difference vectors corresponding to 1 symbol of the signal series subjected to convolution integration, an addition section for sequentially adding up the difference vectors, memory for calculating addition difference vectors in the same way by shifting the reception signal series by 1 sample at a time and storing the type of the known signal series, the time of shifting and the addition difference vectors associated with one another and a detection section for detecting parts that satisfy a specific condition from the vectors stored in the memory.

This configuration makes it possible to detect a target known signal series from the reception signal and

detect the known signal series sent from a plurality of
known signal series candidates and the reception time
with stable performance from the reception signal series
received in a harsh CNR environment.

5   The radio reception apparatus of the present
invention comprises a shift register for storing a series
of reception signals, a known signal storage section for
storing a series of known signals, a convolver for
calculating convolution integration between symbol

10   number s given by the calculation length determination
section from a series of known signals sequentially
output from the known signal storage section and a series
of signals corresponding to s symbols selected at symbol
intervals from the reception signal series, a difference

15   calculation section for calculating difference vectors
corresponding to 1 symbol of the signal series subjected
to convolution integration, an addition section for
sequentially adding up the difference vectors, memory
for calculating addition difference vectors in the same

20   way by shifting the reception signal series by 1 sample
at a time and storing the time of shifting in association
with the addition difference vectors, a detection
section for detecting parts that satisfy a specific
condition from the vectors stored in the memory, a

25   reception situation estimation section for estimating
the reception situation from the reception signal and
a calculation length control section for controlling the
calculation series length of the convolver from the

estimated reception situation.

This configuration makes it possible to detect a target known signal series from the reception signal and detect the reception time of the known signal series from the reception signal series received while changing optimal calculation series length s from the estimated CNR and adapting to the CNR environment adequately.

The radio reception apparatus of the present invention comprises a shift register for storing a series of reception signals, a known signal storage section for storing a series of n (n: natural number of 2 or above) known signals, a switching section for switching between known signal series, a convolver for calculating convolution integration between symbol number s given by the calculation length determination section from a series of known signals sequentially output from the known signal storage section and a series of signals corresponding to s symbols selected at symbol intervals from the reception signal series, a difference calculation section for calculating difference vectors corresponding to 1 symbol of the signal series subjected to convolution integration, an addition section for sequentially adding up the difference vectors, memory for calculating addition difference vectors in the same way by shifting the reception signal series by 1 sample at a time and storing the type of the known signal series, the time of shifting and the addition difference vectors associated with one another, a detection section for

detecting parts that a satisfy specific condition from the vectors stored in the memory, a reception situation estimation section for estimating the reception situation from the reception signal and a calculation length control section for controlling the calculation series length from the estimated reception situation.

This configuration makes it possible to detect a target known signal series from the reception signal and detect the known signal series sent from a plurality of known signal series candidates and the reception time from the reception signal series received while changing optimal calculation series length from the estimated CNR and adapting to the CNR environment adequately.

The radio reception apparatus of the present invention comprises a shift register for storing a series of reception signals, a known signal storage section for storing a series of known signals, a calculation length determination section for determining a calculation series length, a convolver for calculating convolution integration between symbol number s given by the calculation length determination section from a series of known signals sequentially output from the known signal storage section and a series of signals corresponding to s symbols selected at symbol intervals from the reception signal series, a difference calculation section for calculating difference vectors corresponding to 1 symbol of the signal series subjected to convolution integration, an addition section for

sequentially adding up the difference vectors, memory
for calculating addition difference vectors in the same
way by shifting the reception signal series by 1 sample
at a time and storing the time of shifting in association

5   with the addition difference vectors, a detection
section for detecting parts that satisfy a specific
condition from the vectors stored in the memory and a
frequency estimation section for estimating a frequency
from the angle of a vector that satisfies a specific

10 condition.

This configuration makes it possible to detect a
target known signal series from the reception signal,
estimate a frequency shift and detect the reception time
of the known signal series and frequency with stable

15 performance from the reception signal series received
in a harsh CNR environment.

The radio reception apparatus of the present
invention comprises a shift register for storing a series
of reception signals, a known signal storage section for

20 storing a series of known signals, a calculation length
determination section for determining a calculation
series length, a convolver for calculating convolution
integration between symbol number s given by the
calculation length determination section from a series

25 of known signals sequentially output from the known
signal storage section and a series of signals
corresponding to s symbols selected at symbol intervals
from the reception signal series, a difference

calculation section for calculating difference vectors corresponding to 1 symbol of the signal series subjected to convolution integration, an addition section for sequentially adding up the difference vectors, memory

5   for calculating addition difference vectors in the same way by shifting the reception signal series by 1 sample at a time and storing the time of shifting in association with the addition difference vectors, a detection section for detecting parts that satisfy a specific

10 condition from the vectors stored in the memory and a frequency estimation section for estimating a frequency from the angle of a vector that satisfies a specific condition.

This configuration makes it possible to detect a

15 target known signal series from the reception signal, estimate a frequency shift and detect the known signal series sent from among a plurality of known signal series candidates, the reception time and frequency with stable performance from the reception signal series received

20 in a harsh CNR environment.

The radio reception apparatus of the present invention comprises a shift register for storing a series of reception signals, a known signal storage section for storing a series of known signals, a convolver for

25 calculating convolution integration between symbol number s given by the calculation length determination section from a series of known signals sequentially output from the known signal storage section and a series

of signals corresponding to s symbols selected at symbol intervals from the reception signal series, a difference calculation section for calculating difference vectors corresponding to 1 symbol of the signal series subjected to convolution integration, an addition section for sequentially adding up the difference vectors, memory for calculating addition difference vectors in the same way by shifting the reception signal series by 1 sample at a time and storing the time of shifting in association with the addition difference vectors, a detection section for detecting parts that satisfy a specific condition from the vectors stored in the memory, a frequency estimation section for estimating a frequency from the angle of a vector that satisfies a specific condition and a calculation length control section for determining the length of the calculation series length of the convolver from the estimation result of the frequency estimation section.

This configuration makes it possible to detect a target known signal series from the reception signal, estimate a frequency shift and detect the reception time of the known signal series and frequency with stable performance from the reception signal series received while changing optimal calculation series length from the estimated frequency.

The radio reception apparatus of the present invention comprises a shift register for storing a series of reception signals, a known signal storage section for

storing a series of n (n: natural number of 2 or above) known signals, a switching section for switching between known signal series, a convolver for calculating convolution integration between symbol number s given

5 by the calculation length determination section from a series of known signals sequentially output from the known signal storage section and a series of signals corresponding to s symbols selected at symbol intervals from the reception signal series, a difference

10 calculation section for calculating difference vectors corresponding to 1 symbol of the signal series subjected to convolution integration, an addition section for sequentially adding up the difference vectors, memory for calculating addition difference vectors in the same

15 way by shifting the reception signal series by 1 sample at a time and storing the type of the known signal series, the time of shifting and the addition difference vectors associated with one another, a detection section for detecting parts that satisfy a specific condition from

20 the vectors stored in the memory, a frequency estimation section for estimating a frequency from the angle of a vector that satisfies a specific condition and a calculation length control section for determining the length of the calculation series length of the convolver

25 from the estimation result of the frequency estimation section.

This configuration makes it possible to detect a target known signal series from the reception signal,

estimate a frequency shift and detect the known signal series sent from a plurality of known signal series candidates, the reception time and frequency with stable performance from the reception signal series received while changing optimal calculation series length from the estimated frequency.

The radio reception apparatus of the present invention comprises a shift register for storing a series of reception signals, a known signal storage section for storing a series of known signals, a calculation length determination section for determining a calculation series length, a convolver for calculating convolution integration between symbol number s given by the calculation length determination section from a series of known signals sequentially output from the known signal storage section and a series of signals corresponding to s symbols selected at symbol intervals from the reception signal series, a difference calculation section for calculating difference vectors corresponding to 1 symbol of the signal series subjected to convolution integration, an addition section for sequentially adding up the difference vectors, a power calculation section for calculating the size of an addition difference vector, memory for calculating addition difference vectors in the same way by shifting the reception signal series by 1 sample at a time and storing the time of shifting in association with the addition difference vector power and a detection section

for detecting parts that satisfy a specific condition from the vectors stored in the memory.

This configuration makes it possible to detect a target known signal series from the reception signal and
5   detect the reception time of the known signal series with stable performance from the reception signal series received in a harsh CNR environment.

The radio reception apparatus of the present invention comprises a shift register for storing a series
10 of reception signals, a known signal storage section for storing a series of n (n: natural number of 2 or above) known signals, a switching section for switching between known signal series, a calculation length determination section for determining the calculation series length,
15 a convolver for calculating convolution integration between symbol number s given by the calculation length determination section from a series of known signals sequentially output from the known signal storage section and a series of signals corresponding to s
20 symbols selected at symbol intervals from the reception signal series, a difference calculation section for calculating difference vectors corresponding to 1 symbol of the signal series subjected to convolution integration, an addition section for sequentially adding
25 up the difference vectors, a power calculation section for calculating the size of an addition difference vector, memory for calculating addition difference vectors in the same way by shifting the reception signal series by

1 sample at a time and storing the type of the known signal series, the time of shifting and the addition difference vectors associated with one another and a detection section for detecting parts that satisfy a specific

5 condition from the vectors stored in the memory.

This configuration makes it possible to detect a target known signal series from the reception signal and detect the known signal series sent from a plurality of known signal series candidates and the reception time

10 with stable performance from the reception signal series received in a harsh CNR environment.

As shown above, the present invention can achieve great effects in synchronization processing especially in a harsh reception CNR environment. Furthermore, the

15 present invention performs processing basically through calculations of difference vectors, which is little affected by frequency shifts in the reception environment, and is therefore extremely effective especially in the case of synchronizing with the system

20 for the first time after power is turned on.

Moreover, since the CNR of a correlation value is relatively high, and therefore estimating a multipath environment using this provides prospects of high estimation results.

25 The present invention is not limited to the above described embodiments, and various variations and modifications may be possible without departing from the scope of the present invention.

This application is based on the Japanese Patent Application No. 2000-042267 filed on February 21, 2000, entire content of which is expressly incorporated by reference herein.